The Accuracy of Census Results
Author(s): Morris H. Hansen, William N. Hurwitz and Leon Pritzker
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the five per cent level. We therefore conclude that the linear logistic hypothesis was confirmed *under the conditions specified here.*[6]

SUMMARY

The controlled experiments on interacting in Project Revere at the Washington Public Opinion Laboratory pursue two objectives equally. For the Air Force, we seek principles to maximize the desired response of any target population to stimulation by airborne leaflets. For sociologists, we seek to test the interactance hypothesis or principle of demographic gravitation. Each of the nine factors or dimensions of "interactance" are being tested in turn, before testing them, and the eight classes of attendant conditions, in combinations.

For a pretest of the *distance factor* a harmonic waning was hypothesized—interacting should wane with the intervening distance between tellers and hearers if other things are equal. A coffee advertising slogan was started among 20 per cent of the housewives in a town with free coffee promised for those knowing it later. The message spread to 82 per cent of the housewives in 2 days. The closeness of fit of data to this harmonic curve of intervening distance was a correlation of .999,

For a pretest of the *time factor*, S-shaped logistic curves for interacting were predicted as a rational hypothesis mathematically *deduced* from the social conditions which specify how the activity is distributed in the population and in time. In a totally new and different situation in which 184 seventh-graders traded 33 messages for prizes, reliable closeness of fit, correlation indices over .95 in uncumulated data were observed between the hypothesized expectation and the later experimentally observed facts.

The dimensional interactance hypothesis expects that the diffusion here (or interacting generally) will depend upon a power or logarithm of each of its nine classes of factors. When the factors of time and space were each isolated in turn in the experiments reported here, the interacting was observed to vary closely and reliably in agreement with the appropriate special case of that very general hypothesis.

[6] This does not preclude better fits by other models here. Nor does confirmation in one experiment constitute confirmation in general, of course. But the experiment here is readily repeatable so that wider confirmation can be tested. It should also be noted that Pretest F, which is reported here for illustration, is one of a dozen pretests in which logistic growth principles were explored in preparation for more rigorous tests in 1953 with the pre-conditions more fully charted.

THE ACCURACY OF CENSUS RESULTS

MORRIS H. HANSEN, WILLIAM N. HURWITZ, and LEON PRITZKER

Bureau of the Census

THE Censuses of Population, Housing, and Agriculture, taken during 1950, required the services of approximately 1,000 field supervisors, 9,000 crew leaders, and 132,000 enumerators. This staff had the tremendous task of covering approximately 151 million people, 46 million dwelling units and 5.4 million farms. From the standpoint of sheer size, it is inconceivable that such a census would be free from errors.

This paper is concerned with two aspects of census errors: their size and their significance. In dealing with the question of size, we shall describe an attempt at measuring some of the errors of the 1950 Census. In dealing with the second question, we shall indicate the important role that sociologists and other users of census data must assume before the significance of census errors can be fully assessed.

Before attempting to deal in any systematic way with the two questions that have been posed, we should like to call attention to a major change in attitude with respect to census taking. Until recently, the emphasis in census taking has been primarily on producing the most accurate census possible, without any particular at-

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tention being given to the question of the required accuracy and to what extent it is worth an additional cost to increase the accuracy. Attempts to evaluate the cost of achieving different levels of accuracy in comparison with the possible costs arising from wrong decisions resulting, in turn, from errors in statistics were stimulated by the introduction of modern sampling methods. In the use of these methods emphasis has been placed on achieving results of needed accuracy at minimum cost and on attempting to consider the overall accuracy required in relation to the costs and the purposes to be served. The objective of "optimum design" in sampling is coming to be the objective in census taking. Instead of striving for perfection, we view the task as that of balancing the costs of producing statistics against the losses from errors in the statistics.

The first topic to be discussed is that of the size of census error, more specifically, the methods and results of an attempt to measure the extent of error in the 1950 Census. It is important at the outset to point out that, if major national aggregates for population, housing, and agriculture characteristics were all that were desired, there would be no need for a complete census. Recent developments in sampling indicate that important national aggregates can be estimated from a sample with accuracy equal to or greater than that of a census at a fraction of the cost of taking a census. A census, however, is required in order to provide data for very small geographic areas or for cross-classifications that involve relatively few people.

The fact that a small well-designed and well-administered sample can yield more accurate measurements than is feasible in the much larger scale operations required for a census suggests the use of the former as a vehicle for checking on the latter. In fact, the Bureau of the Census and other statistical agencies have used this second approach to study the accuracy of censuses.[1] Such sample evaluations started on a systematic basis in the United States with the 1945 Census of Agriculture and continued with the 1947 Census of Manufactures and the 1948 Census of Business.

In the 1950 Censuses of Population, Housing, and Agriculture, a major project was undertaken on a sample basis to evaluate both the completeness of coverage and the accuracy of response to selected inquiries for the units (persons, dwelling units, farms) included in each Census. This project was called the Post-enumeration Survey (or PES) and had two major purposes. The first purpose was to provide a measure of accuracy of the results of the Census in order to aid the consumer of Census data in avoiding the drawing of inferences that would be unwarranted by the accuracy of the data. The second purpose was to ascertain sources of error and the size of error associated with each source. Such information, supplemented by evidence on the cost of eliminating or reducing the causes of error, provides information needed to improve census design. Thus, costs of achieving various levels of accuracy can be balanced against the requirements of the users of the data. Obviously, if there were no problem of increased cost in achieving a perfect result, we would try for perfection, but as a practical matter this is not the case.

Calling the project the "Post-enumeration Survey" was a consequence of a major decision made in the planning stages. This decision was to conduct the "quality check" *after* all phases of the Census had been completed in the field. Some discussion of how this decision was reached may be appropriate:[2] The alternative to conducting the "quality check" after the Census that was considered was that of conducting the check at the same time as the Census.[3] In line with this alternative, the Current Population Survey carried out monthly by

[1] See: Gabriel Chevry, "Control of a General Census by Means of an Area Sampling Method," *Journal of the American Statistical Association,* Vol. 44 (1949), pp. 373–379. A. Ross Eckler and Leon Pritzker, "Measuring the Accuracy of Enumerative Surveys," *Proceedings of the International Statistical Institute,* New Delhi, India, 1951.

[2] For an account of some of the decision making for the Post-enumeration Survey, see Marks, Mauldin, and Nisselson, "A Case History in Survey Design, the Post-enumeration Survey of the 1950 Census," to appear in the *Journal of the American Statistical Association.*

[3] There was also the third (and meaningful) alternative of conducting the check *prior* to the Census.

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the Bureau of the Census was considered as the vehicle for the check. In fact, this Survey was used to throw light on the accuracy of some of the more dynamic inquiries included in the Census, particularly labor force participation.

The Current Population Survey was also considered as the basis for checking the accuracy of other characteristics such as the coverage of the Census, the age distribution, the income distribution, the pattern of educational attainment, the tenure status of dwelling units, the uses of farm acreage, and so on. One of the main advantages of using the Current Population Survey for conducting a quality check at the same time as the Census is that the effect of memory bias on the results of the quality check itself is eliminated. However, there were some major disadvantages in the use of the Current Population Survey as a concurrent quality check. Any quality check procedure which could be construed as a "whitewash of the Census" would lose public acceptance. It was thought by many that comparisons of Census information with sample information for households included in the monthly sample, or even from other households selected in the same sample areas as were used in the Current Population Survey, might "condition" the Census results. With this sample the areas to be checked would be known in advance to many of those participating in taking the census, and such knowledge might have the effect of increasing the quality of the census in the areas that were to be checked. Also, the areas in the Current Population Survey might, on the whole, have better trained supervisors and enumerators than other areas. It was thought that these factors might lead to understatement of the differences between the Census and the quality check.

It was decided, therefore, that it would be desirable to conduct the quality check for characteristics other than labor force participation after the Census was taken. It was decided also not to disclose the locations of the quality check sample areas until the Census was completed. Moreover, the decision was made to assign quality check supervisors and interviewers to areas other than those in which they worked during the Census.

There were other reasons for not conducting the quality check at the same time as the Census (or even immediately following the completion of the Census in a given area). These reasons had to do with the desirability of making available to the quality check interviewers the records of the Census enumeration for the sample areas to be checked. We could find no feasible way of doing this such that the quality check could be carried out at the same time as or immediately following the Census in a given area. In our view, ability to study many characteristics does not deteriorate with time, as, for example, the determination of age. The decision in favor of a *post*-enumeration survey was predicated in part on the hypothesis that the effect of memory bias is not severe for many items. For example, whether one interviews to ascertain last year's income during April and May or during August and September may not lead to significantly different results because of the passage of time. We need further evidence on this hypothesis, since it contradicts many widely held opinions.

Thus, the decision was made to conduct a *post*-enumeration survey. In order to describe more fully the methods of the PES we shall limit the discussion to its use in the Population Census.

A major aim of the PES was the measurement of *net coverage error*. This measure is obtained by making estimates of two other measures. The first is the estimate of people not included in the Census who should have been included (gross under-enumeration in the Census), and the second is the estimate of names included in the Census that should not have been (gross over-enumeration in the Census). The net under (or over) coverage error is the difference between these two.

Another major objective was the evaluation of the accuracy of responses recorded on the Census schedules for persons included in the Census, in an effort to study age, income, occupation, and other characteristics. Here, the interest was in studying the extent of the *net bias in reporting* as well as of gross error in reporting. It should be clear that we can have errors of over-enumeration and under-enumeration and still have no net coverage error. In

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the same way, a particular characteristic such as age may have no great net bias in reporting, that is, the over-reporting of age may balance the under-reporting. The PES was designed to measure both such gross and net errors.

To achieve these objectives the sample for the Post-enumeration Survey was divided into two major parts. The first part was a sample of areas, and the second was a sample of dwelling units from the Census. The sample of areas was to be recanvassed intensively in order to locate any dwelling units in each area that were not included in the Census but should have been. The sample of dwelling units drawn from the Census returns was used in making three estimates: (1) the number of persons not included in the Census, who lived in dwelling units that were properly enumerated; (2) the number of persons enumerated in these dwelling units, who should not have been included in the Census; and (3) the accuracy of response to selected questions included in the Census.

It should be pointed out that the coverage evaluation was made in relation to Census enumeration districts. That is, we regarded a person as left out of the Census if he was not enumerated in the Census enumeration district in which he should have been enumerated, even though he might have been included elsewhere. We regarded a person as included in error if he was included in a Census enumeration district where he should not have been, even though he was not included anywhere else. Thus, the gross errors are stated in relation to the areas defined for taking the Census because it was with respect to these areas that the rules were laid down as to who should and who should not be counted by each enumerator. The effect of determining the gross error in coverage for enumeration districts is to over-state this error for areas larger than enumeration districts. The expected net coverage errors are not overstated, however.

For the evaluation of the accuracy of response to Census inquiries, the PES was limited to selected items. Among the items studied in the check on the Population Census were age, income, occupation, educational attainment, migration, and birthplace. For most of these items a more intensive approach to questioning was introduced in the Post-enumeration Survey than was feasible in the Census itself. For example, the Census asked in order to determine "wage and salary" income for a person, "Last year (1949), how much money did he earn working as an employee for wages and salary?" The PES, on the other hand, used a battery of questions designed to uncover all the jobs a person held in 1949 and the gross income from each job.

Other steps taken in the Post-enumeration Survey to improve accuracy, not only of response on subjects covered in the Census, but on the coverage check itself, included the following:

(1) The personnel for carrying out the PES was selected from among the best enumerators and crew leaders who had worked on the Census. There were three criteria: (a) a high score on selection tests, (b) excellent performance in the Census insofar as performance could be evaluated, and (c) recommendations by the field supervisors.

(2) PES interviewers were given special training, far more intensive than was possible in the Census itself.

(3) Instead of being paid on a piece rate basis, as in the Census, the interviewers were paid a daily rate to get away from any possible incentive to sacrifice quality.

(4) It was specified in the PES that data be obtained from the best respondent for each question, as distinguished from the situation in the Census, where the housewife frequently answers for other members of the family. It is often presumed that one of the problems in the Population Census arises in the collection of statistics on occupation and industry, for example, because the data are frequently collected from the housewife instead of from each worker individually. In the PES steps were taken to ask the question of the best respondent, and a great amount of effort was expended in pursuit of this best respondent. In the case of youngsters and certain incompetents this best respondent would be the mother or some other specified member of the family.

We have outlined a number of very important changes in procedures, method and emphasis, in the Post-enumeration

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Survey as compared to the Census, that should lead to a presumption that the PES will yield more accurate results. However, it should be recognized that this is only a presumption. The PES and the Census are both subject to error; this must be kept in mind in any interpretation of the results.

In fact, the PES was far from a perfect instrument for measuring the size of Census errors. This is seen, for example, by the results of a small-scale check made on the PES itself. This "check on check" revealed missed dwelling units that were not detected by the PES interviewers. Also, there were errors in drawing the sample and in processing the results. Finally, the PES results on the numbers of missed persons classified by age do not accord with some evidence from other sources.

Although there were important errors made in the PES, it appears quite reasonable to assume that the quality of work was such as to provide a standard of comparison for the Census that was in many important respects more reliable than the Census itself.

We have introduced a series of "record checks," moreover, to provide evidence on the accuracy of response in the PES as compared with response in the Census. For example, a check on income reports in the Census is being made against Bureau of Internal Revenue income tax returns. Veteran status reports to the Census and to the PES are being compared with the records of the Veterans Administration. Ages reported in the Census and the PES are being compared with birth records and with earlier Census reports. Also, a check is being made of industry reports and wage and salary income reports in the Census by comparison with the records of the Bureau of Old Age and Survivors Insurance. These record checks are carried through on a matched basis, person by person. For the names that are successfully matched, a comparision is made of the information in the agency's record with that from the Census and the PES. Presumably, more accurate information is contained in such records.

Those who have attempted to carry through such matching studies will be immediately aware of the very great difficulty of matching the information from one source such as the Census against that from another source such as Social Security records. The existence of dubious matches as well as of unmatched cases makes it difficult to draw any direct inferences concerning the accuracy of the Census. We have assumed, however, that these independent records could be effectively used to evaluate the PES results as compared with the original Census returns by examining only those cases in which reasonably positive matches have been established. Thus, it is assumed that comparison, for only the matched cases, of the PES reports and the Census reports with the independent data provide a basis for testing the hypothesis as to the relative accuracy of the PES and Census reports.

Thus far in our discussion of the study of accuracy of the Population Census we have outlined some of the methods used in the PES, some of its limitations and, finally, a proposed technique for "validating" the PES (the record check). Now, let us consider some of the results. Only the measures of coverage error are available at this time. The total omissions of persons from the Census in enumeration districts where they should have been enumerated was 2.3 per cent with a standard error of 0.2 per cent. The number enumerated who should not have been was 0.9 per cent with a standard error of 0.1 per cent. This leaves a net omission rate of 1.4 per cent plus or minus 0.2 per cent, or about 2 million plus or minus 340,000 people. Differences between age groups were not as striking as were expected. As between urban and rural, the underenumeration seems to be somewhat greater in the very large cities and the more rural areas. The curve appears to be U-shaped, with lower omissions in the smaller size cities. The net relative undercoverage of non-whites was about two and a half times that of whites.

Knowledge of the sources of the discrepancies in coverage provides a basis for considering further action. For example, techniques for dealing with the problem of underenumeration can arise from learning that about two-thirds of the persons erroneously omitted from the Census were in households where the entire household was missed and about a third were missed

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within enumerated households. Within enumerated households the highest rates of underenumeration were among people who were not members of the immediate family, such as lodgers, servants, fathers- or mothers-in-law, and similar groups. Apparently the probability of being missed increases with the remoteness of the relationship to the family.

It is important to note that the PES measures of underenumeration do not include persons who live in hotels and in institutional places. The problem of underenumeration in such living quarters is being studied, too, and the results will be reported subsequently. For this and other reasons, it is reasonable to regard the estimates above as indicating a lower limit on the net underenumeration in the Census. Some of the people whom the original Census takers missed may also have been missed by the PES interviewers. It appears, on the other hand, that the PES may be expected to have identified overenumeration more adequately, since the names of those included in the Census were on hand. The PES needed only to verify their existence and the appropriateness of their inclusion by the Census enumerators.

Persons erroneously included are of two types: names that should not have been listed anywhere, and persons who have been enumerated in the wrong enumeration district. Names that should not have been enumerated anywhere include any "padding" or fabrication of the records that may have taken place. We were particularly interested in this latter figure. We were pleasantly surprised that the estimates of padding by the Census enumerators amounted to less than a tenth of one per cent of the enumerated United States population. This is a far smaller figure than some of the people working with the Census had feared, after having seen the individual cases uncovered and the prosecution of enumerators and others in the isolated instances that came to attention.

Nearly all of the names that were listed in error were those of persons who should have been enumerated in other enumeration districts. These account for the bulk of overenumeration, or about 0.8 per cent, out of the total 0.9 per cent enumerated in error. They include people who had claims to two or more residences for one reason or another. The problem of describing the appropriate place to enumerate people who travel and work, or have no usual place of residence or maintain two or more places of residence is a most difficult one. The problem is made more difficult because the Census enumerator is paid on a piece rate, which creates an incentive for him to get as many people as he can.

Until now, we have been considering the problem of how we have gone about measuring the errors in Census statistics, and some results of the measurements made, and not of what accuracy requirements should be imposed on Census results. What should our goal be, and how can we arrive at it? What is the significance of census errors? This is a problem deserving of very careful attention and consideration by groups such as the American Sociological Society as well as the Bureau of the Census. Until recently, it is safe to say that the philosophy of the staff at the Bureau of the Census, and in general of the advisors to the Bureau and of most users of Census data, was that we should strive for perfection and try to get the most accurate measure possible of anything that we were trying to measure. The subject of the relationship of accuracy to the utility of the results has not received much serious attention in the literature until very recently, and much of what has been written is in terms that are difficult to apply to practical problems. Very often people have considered the question of accuracy and have not considered the question of utility, and conversely the question of utility has been discussed in a conceptual setting rather than in terms of the accuracy of measurement of a particular statistic used for particular purposes. We believe that a solution of the problem calls for, among other things, recognition of the principle that considerations of accuracy and of utility are inseparable. We have been forced to this recognition by having to view the Bureau of the Census as a factory engaged in the production of statistical tables. In the management of that factory, just as in the management of any other factory, it is necessary to make, in some sense, the input of the factory comparable with its output. Management is required to examine the

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costs of production and relate them to the value of what is produced. The value of our product depends on the uses that are made of it and, depending on the use and the risks and losses associated in making a mistake in the use, the allowable tolerances of error may vary. Instead of the principle of highest possible accuracy, then, this view substitutes the principle of determining the level of accuracy that is optimum by balancing the losses due to errors against the costs of greater accuracy.

Considerations of this sort have already led to considerable modification in some of the methods in Census work. The Bureau has, by design, reduced the accuracy of compilation, where errors are subject to close control and were on a near zero basis. Higher error tolerances have been introduced in processing work, controlled at specified levels through quality control or sample verification and other techniques. The considerable economies which have resulted have made it possible to take additional steps to try to improve the quality of the field work, where error levels are considerably higher.

In order to achieve desired levels of accuracy three kinds of information are required. All three kinds require the extension of the idea of using a measurable design, developed in modern sampling theory, to the entire survey or Census process. The three kinds of information can be characterized as follows:

(1) Knowledge about the cost and accuracy of alternative methods of conducting the same survey.

(2) Knowledge about the accuracy actually achieved in a given survey.

(3) Knowledge about the accuracy required for a given survey. This in turn requires knowing how the statistics are to be used and what the risks and losses associated with inaccuracy are.

On the first two points we are beginning to amass a body of techniques which help to tell us something about the accuracy associated with our methods and the accuracy of given results. On the last point we must, at least at this stage of our development, rely largely on our collective intuitions and on the implicit evaluation made by the Congress through setting appropriations. With respect to the accuracy of alternative methods, we use the pretest and pilot study, and have initiated a series of research projects to test alternative procedures and to estimate the cost associated with them. For example, a major test was carried through in the recent Census comparing the use of self-enumeration versus direct interviewing to collect Census data in the fields of population, agriculture, and housing. We are comparing methods of mark sensing with other methods of recording information. We are studying different methods of compilation. We are working on the development and application of electronic computing equipment. Similarly, we are studying the effect of the contribution of the interviewer to response error. Also, we are trying to develop methods of quality control for field operations that are as satisfactory as those for operations in the processing of the returns.

Results from such activities should make it possible to come closer to the ideal of an optimum design for a sample survey or a census.

A necessary condition for progress, however, is to obtain better answers to the question, "What accuracy should we try to buy?" Perhaps that is stating it the wrong way. Perhaps we should ask, "What are the losses associated with differing levels of accuracy?" Suppose, for example, we could succeed in changing the completeness of the Census from a net underenumeration of 1.4 per cent to a net underenumeration of, say, 0.4 per cent, and that we could specify what it costs at each fraction of a percentage point along the way to achieve that level of accuracy. To what extent is the additional accuracy worth the price and to what extent is it not? The same types of questions arise in measuring employment, marital status, fertility, and other characteristics. Frequently by the use of appropriate methods and the expenditure of additional resources we can use measurement methods such that the results will converge closer and closer to the true value of the characteristics being measured, although they will not necessarily approach it with an error close to zero for any plausible budget.

What, then, are the levels of accuracy

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that are justified by the cost required to achieve them? The advisors to the Census and the users of Census and other statistical data need to give more and more attention to such questions if we are to serve adequately our function of collecting and making available useful and adequate statistics. The cost of achieving the level of accuracy which we now attain is appreciable. In this last Census, for example, we introduced a hotel check in which all persons staying in hotels were enumerated on "T night" (night for enumeration of transients), no matter where the hotels were located nor where the guests had their usual residence. Then the records of this enumeration were taken back and checked against the guests' usual place of residence to see if they were enumerated there. This innovation of the 1950 Census cost about an extra million dollars. Also, it added about 700,000 people (0.4 per cent) to the Census. Was it worth this cost? Other steps of a similar nature could be taken. They might be costly and also time consuming in the Census operation. Any major gains that might be accomplished at little or no cost should obviously be taken, but this whole area of the relation between cost of achieving different levels of accuracy and the effect of different levels of accuracy on the utility of results is of the greatest importance.

Among the more specific types of decisions that we must face in this connection is the answering of questions such as: Should we have carried through and should we, in the next Census, carry through a hotel check similar to the one just described? Should we pay an additional price for a Census in order to shorten the period of the Census?

More generally the following questions must be answered:

(1) Is it more important to have more statistics (that is, statistics on a large number of subjects or more detailed statistics on the same subject) than to have more accurate statistics?

(2) Is it more important to have more statistics or to spend funds in obtaining measurements of the errors of the statistics already obtained?

(3) Is it more important to use funds in increasing the accuracy of statistics? If so, how can we know to what extent we are effective?

These are difficult questions. As a practical matter, such questions have to be answered. Even to approach consideration of these questions there must be a presumption that we can measure not only sampling errors but also response errors, errors in compilation, and perhaps what might be called errors due to the types of measures selected (errors arising from the choice of inappropriate definitions, for example).

Some progress has been made in answering the three questions that we have posed simply by the efforts to measure errors in statistics. The study of the significance of Census errors can only be advanced in the long run, however, when sociologists, economists and others who use Census results face up to their responsibilities.

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